SpW-10X Network Performance Testing

Peter Mendham, Jon Bowyer, Stuart Mills, Steve Parkes

Space Technology Centre

University of Dundee

Before I Start...

- POR configuration of 10X
- Sets defaults for each port
  - Bits 2-0: Port transmit divider
  - Bit 3: Self addressing enable
  - Bit 4: Enable timeouts
  - Bit 5: Long or short timeouts
  - Bit 6: Start on request
  - Bit 7: Disable on silence
- From AT7910E user manual:
  - http://www.atmel.com/
  - Then just search for AT7910E

Space Technology Centre
University of Dundee

Agenda

- Aims
- Hardware development
- Implementation
- Test setup
- Test overview
- Issues identified
- Additional observations
- Conclusions

Network Performance Testing Aims

- Evaluate performance of SpW-10X ASIC in practical scenarios
- Load stress testing
- Boundary case testing
- Throughput testing
- Evaluation of FDIR configurations

Hardware Development

Space Technology Centre
University of Dundee

Test Board Development

- Two stage solution to minimise risk
  - Motherboard
  - Daughterboard carrying ASIC device
- Motherboard provides:
  - Direct (un-buffered) breakout of all signals to test headers
  - DIL switches for all inputs
  - External connectors for FIFO and time-code ports
- Daughterboard:
  - FPGA version for early functional testing
  - FPGA daughterboard previously tested
  - Permitted validation of motherboard
  - ASIC version used when motherboard was proven

Space Technology Centre
University of Dundee

Additional Motherboard Features

- Interfacing logic to permit:
  - Loopback on FIFOs with no external cable
  - Loopback between FIFO ports with provided cable
  - FIFO interfacing between units
  - Clock mastering or slaving to a choice of ports
  - Time-code mastering and slaving to a different unit or an external development board
- Facilities for daisy chaining on resets
  - Master reset
  - Time-code reset

Space Technology Centre
University of Dundee

Additional Daughterboard Features

- Over-current protection
- Over-voltage protection
- Test points for current and voltage measurement

Space Technology Centre
University of Dundee

PCB Specification and Layout

- 6U Eurocard sized PCB
- Fits into standard enclosure
- Four-layer PCB with continuous ground and power planes
- Source termination and careful grounding arrangements for high-speed logic signals
- ESD protection on all external signals

Implementation

Space Technology Centre
University of Dundee

Motherboard Implementation

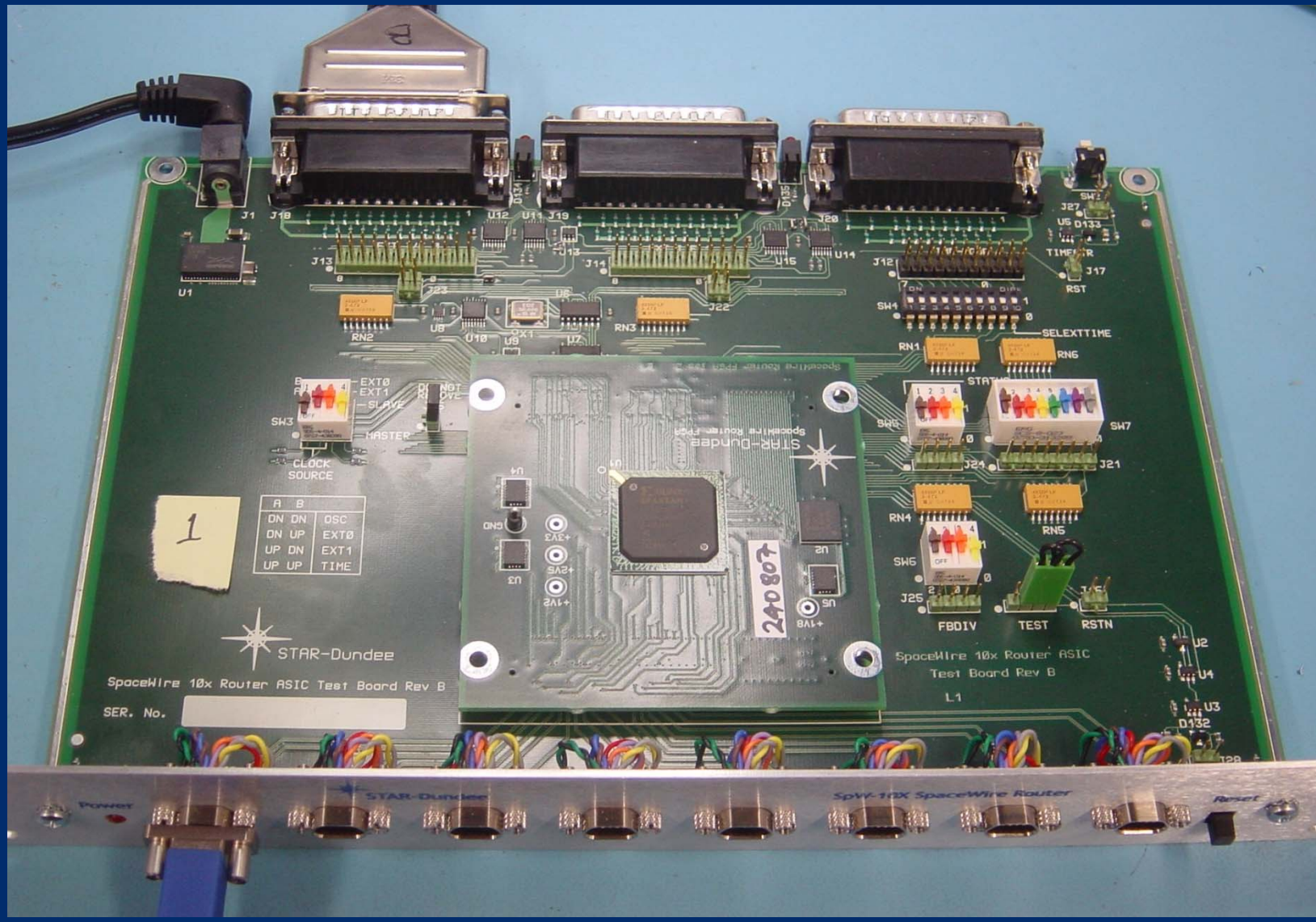
- Revision A:
  - Functionally correct
  - Minor issues with schematic symbols causing layout problems
  - Clock signal integrity issues in certain scenarios
- Revision B:
  - All issues resolved
  - No signal integrity problems
  - Additionally, feedback from early testing was incorporated
    - Clearer silkscreen
    - More consistent test header layout

Space Technology Centre
University of Dundee

Daughterboard Implementation

- No issues found

Motherboard (with FPGA DB Fitted)



Space Technology Centre
University of Dundee

ASIC Daughterboard

Space Technology Centre
University of Dundee

Space Technology Centre
University of Dundee

Enclosed Unit

Space Technology Centre
University of Dundee

Test Setup

Test Equipment

- Four SpW-10X Test Systems
- Up to four of each of the following:
  - STAR-Dundee Link Analyser
  - STAR-Dundee Conformance Tester
- Up to seven STAR-Dundee SpaceWire-USB Bricks
- STAR-Dundee laboratory SpaceWire cables
- Supporting STAR-Dundee software
- STAR-Dundee CUBA software and scripts for test automation
- STAR-Dundee SpaceWire Demonstration System

Typical Test Setup (1)

Space Technology Centre
University of Dundee

Typical Test Setup (2)

Space Technology Centre
University of Dundee

Space Technology Centre
University of Dundee

SpaceWire-USB Brick

- Three-port router
- Two SpaceWire ports
- One USB port
- Same base IP as the SpW-10X router
- Full software support:
  - Drivers
  - Examples
  - Graphical test tools
  - CUBA script-driven software
- Used for:
  - SpW-10X configuration over RMAP
  - SpaceWire Demonstration System

Space Technology Centre
University of Dundee

SpaceWire Link Analyser

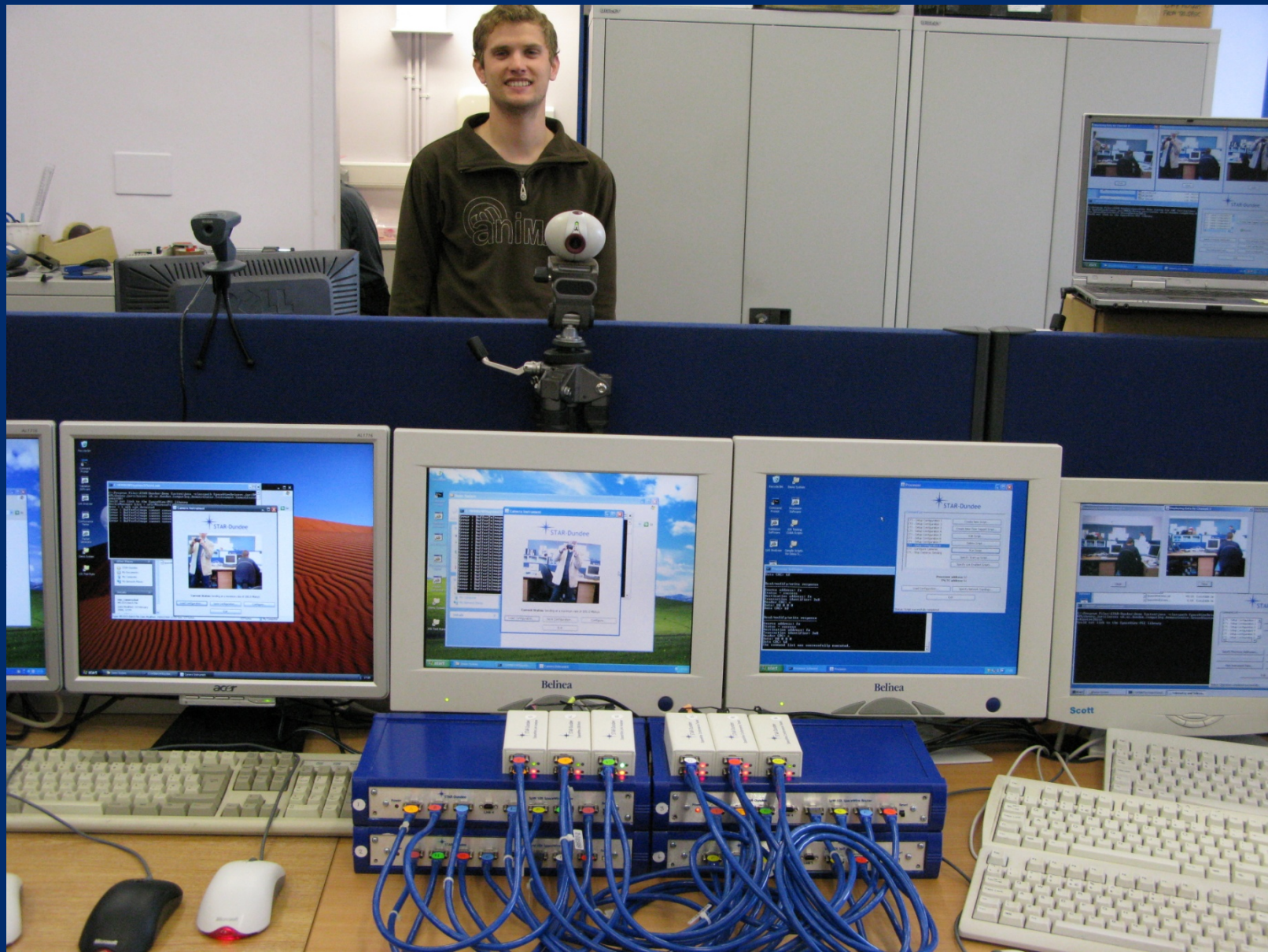
- Transparent link analyser
- Bit level traffic recorder
- Precise timing (down to 1.4 ns)
- Highly configurable triggers
- Graphical user interface
  - Easy to use
  - Bit-level, character level and packet level views
- Used for:
  - Test verification
  - Results gathering

Space Technology Centre
University of Dundee

SpaceWire Conformance Tester

- Sophisticated low-level to high level tests for SpaceWire conformance
- Covers all tests that are possible without active cooperation of the UUT
- Graphical software tied closely to the SpaceWire standard
- Highly versatile packet generator
- Used for:
  - High speed packet generation

Testing (with a Happy Tester)



Space Technology Centre
University of Dundee

Test Overview

Space Technology Centre
University of Dundee

Traffic Load Stress Tests

- Aim:
  - To check the operation of the SpW-10X Router ASIC when packets of various sizes are sent continuously at maximum data rate
  - This checks the packet multiplexing capability of the SpW-10X device
- Tests:
  - ST1 Many Ports to One Port
  - ST2 Many Ports to Many Ports
  - ST3 Group Adaptive Routing
  - ST4 Priority Routing

Space Technology Centre
University of Dundee

Boundary Case Tests

- Aim:
  - To check the operation of the SpW-10X Router ASIC when blocking occurs
- Tests:
  - BT1 Blocking Recovery

Space Technology Centre
University of Dundee

Throughput and Power Tests

- Aim:
  - To measure the maximum throughput of the SpW-10X device under various load conditions
  - The power consumption of the SpW-10X device will also be measured under various operating conditions (all at room temperature)
- Tests:
  - TT1 Throughput and Power vs. Data Rate
  - TT2 Throughput and Power vs. Number of Links
  - TT3 Throughput and Power vs. Packet Size

Space Technology Centre
University of Dundee

Cross-Strapping, Redundancy and Reconfiguration Tests

- Aim:
  - To check the SpW-10X device when it is configured to support the following redundancy:
    - Link redundancy
    - SpW-10X redundancy
- Tests:
  - RT1 Link Redundancy
  - RT2 Router Redundancy
  - RT3 Router Redundancy

Space Technology Centre
University of Dundee

Cascading Tests

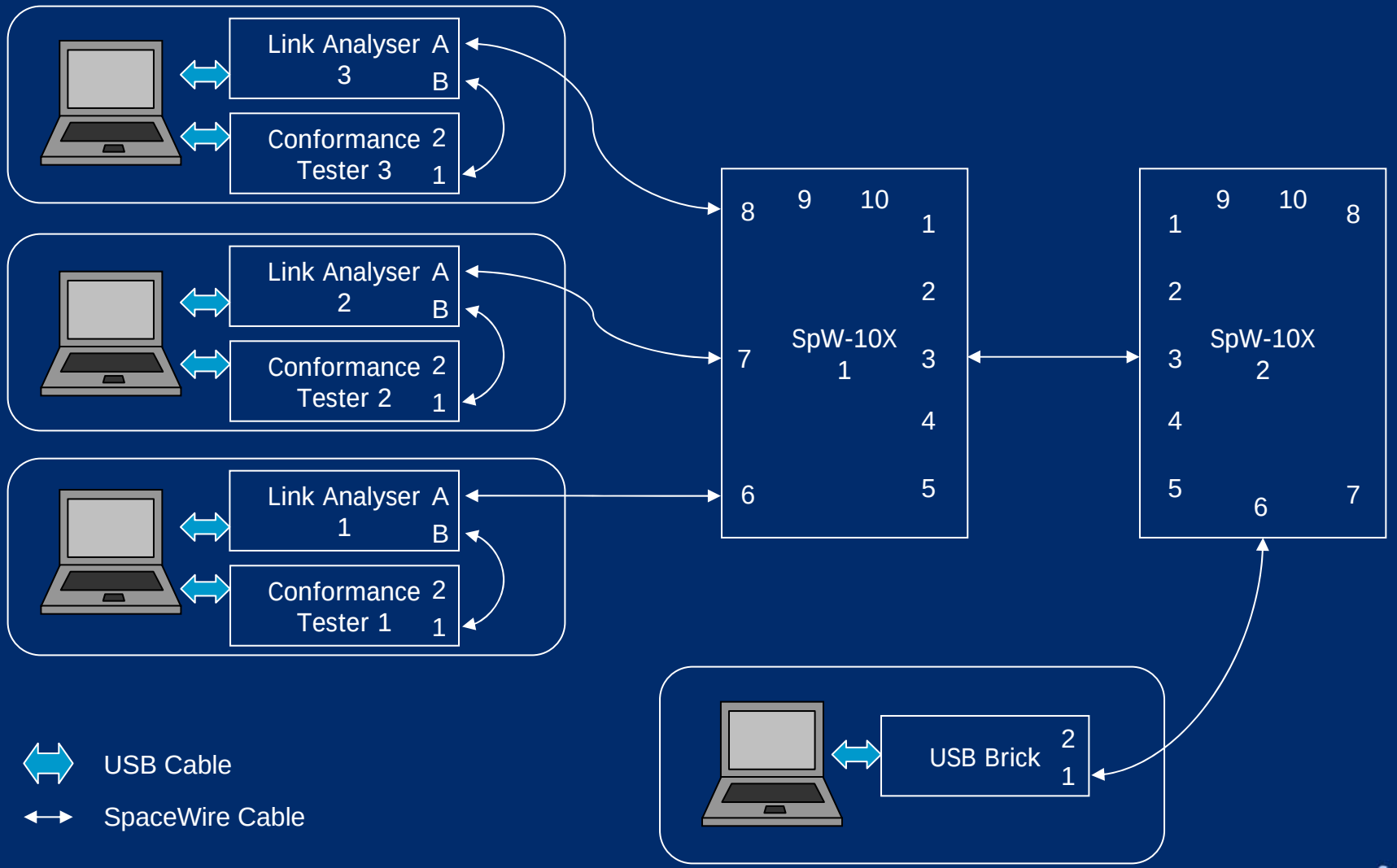
- Aim:
  - To check that multiple cascaded routers function correctly
  - It should be noted that since the SpaceWire-USB Bricks used in all tests contain a SpaceWire router, extensive cascade testing has already been done
  - The aim here is to specifically test cascading on the SpW-10X devices
- Tests:
  - CT1 Router Cascading

Issues Identified

Test ST4: Priority Routing

- Objective:
  - To determine if the SpW-10X can successfully route packets from multiple sources over the same port, giving precedence to high priority packets over low priority packets
  - Checks the operation of the priority mechanism in the SpW-10X device

ST4 Test Setup



Space Technology Centre
University of Dundee

ST4 Issues

- Test plan specified expected behaviour:
  - high priority packets using all available capacity
  - normal priority packets not getting routed at all
- Test plan also proposed that this would be avoided by introducing inter-packet delays between high priority packets
- Results (shown later) show that actual behaviour is:
  - number of normal priority packets from packet generator 2 is 50% of the number of high priority packets from packet generator 1
  - number of normal priority packets from packet generator 3 is 50% of the number of high priority packets from packet generator 1

Space Technology Centre
University of Dundee

ST4 Issues

- Reason:
  - at the instant when one of the high priority packets finishes being transferred by the router, the next packet from that sender is not yet waiting (it's header is being decoded)
  - therefore a low priority packet from one of the other senders (which is already waiting) can be routed instead
- To further investigate behaviours, two additional tests carried out
  - Second Test: Packet Generators 1 and 2 both sending high priority packets
  - Third Test: Same as second test but with inter-packet delay of 2μs on Packet Generators 1 and 2

ST4 Results

Space Technology Centre
University of Dundee

Original Test	Received from 10X number 1 during 10 minute test period		
	Packet Generator 1 (HIGH Priority)	Packet Generator 2 (Normal Priority)	Packet Generator 3 (Normal Priority)
Data Characters	4,708,908,051	2,355,360,172	2,353,021,110
Data Characters as % of packet generator 1 value	100%	50%	50%

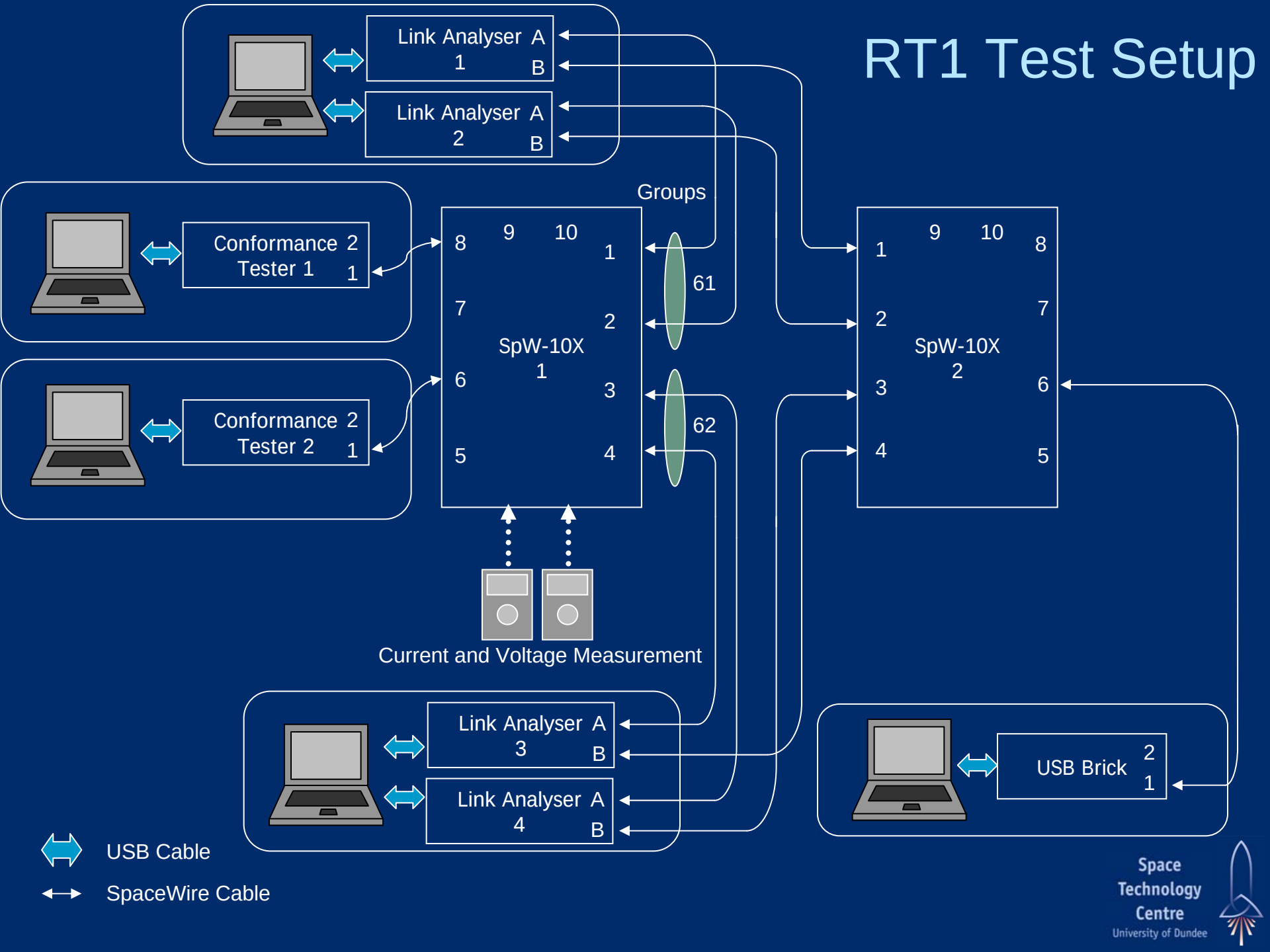
Second Test	Received from 10X number 1 during 10 minute test period		
	Packet Generator 1 (HIGH Priority)	Packet Generator 2 (HIGH Priority)	Packet Generator 3 (Normal Priority)
Data Characters	4,813,845,056	4,809,908,180	0
Data Characters as % of packet generator 1 value	100%	100%	0%

Third Test	Received from 10X number 1 during 10 minute test period		
	Packet Generator 1 (HIGH Priority)	Packet Generator 2 (HIGH Priority)	Packet Generator 3 (Normal Priority)
Data Characters	3,700,334,691	3,703,179,191	2,075,626,476
Data Characters as % of packet generator 1 value	100%	100%	56%

Test RT1: Link Redundancy

- Objective:
  - SpaceWire's group adaptive routing can be used to switch to a redundant link in the event of a failure on an equivalent link
  - The link redundancy tests will investigate the effect on traffic when the SpW-10X switches to a redundant link

RT1 Test Setup



Space Technology Centre
University of Dundee

Space Technology Centre
University of Dundee

RT1 Issues

- Link analyser data from the second iteration of the test (with Disable on Silence) were similar to their equivalents from the first iteration of the test
- Reason: With group adaptive routing, all output links for a given logical address are kept running as long as packets are arriving for that logical address
  - Therefore in this test all links are kept running regardless of Disable on Silence
- This fact was overlooked when the expected results were specified

RT1 Power Consumption Results

For this reason, power consumption results from both test iterations are similar, except for the final reading after the packet generators have been stopped, at which point Disable on Silence can then operate

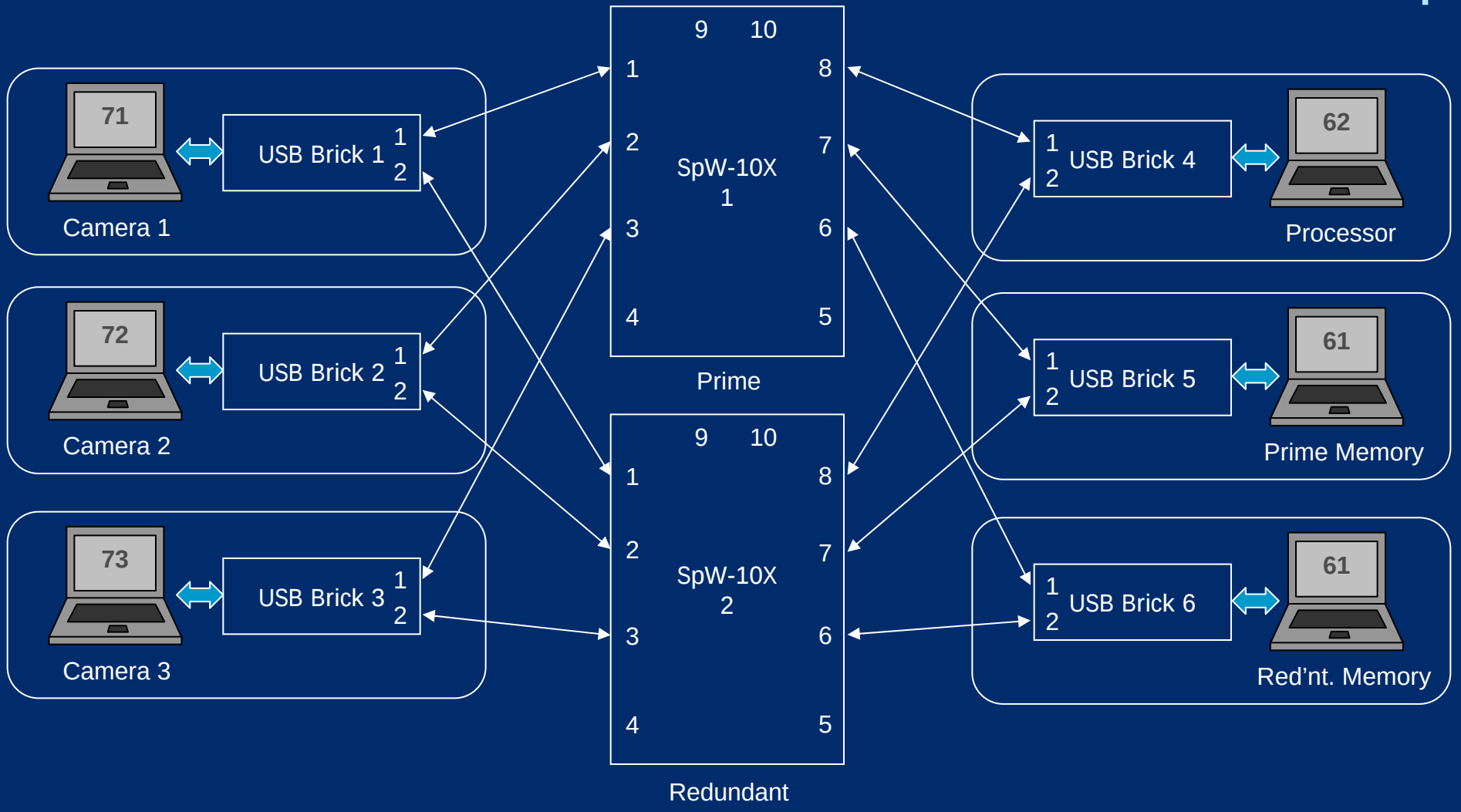
	10X number 1 Power Consumption (W)	
	Test Iteration 1	**Test Iteration 2 (Disable on Silence Enabled)**
No Ports Disabled	2.14	2.14
After Router 2 Port 1 Disabled	2.08	2.08
After Router 2 Port 3 Disabled	2.02	2.02
After Packet Generators stopped	1.86	1.73

Space Technology Centre
University of Dundee

Test RT3: Router Redundancy

- Objective:
  - To test the SpW-10X device in a configuration with several instruments each sending data through a prime or redundant SpW-10X device to a prime or redundant memory unit
  - The system is configured by a processor unit
  - The memory unit is redundant and tests will be made sending to both prime and redundant memory units
  - For ease of running the tests the processor unit is not redundant

RT3 Test Setup



Space Technology Centre
University of Dundee

Space Technology Centre
University of Dundee

RT3 Issues

- Due to Prime / Redundant memory being selected by enabling/disabling of links on the 10X routers, powering routers off and on had the side-effect of un-doing this selection
  - any links that were disabled became re-enabled when router powered on again
  - therefore the memory unit being used could be unintentionally changed

RT3 Issues

- If Prime router was configured to use the Prime memory, Redundant router was configured to use the Redundant memory, both routers powered on, and Prime memory PC was slow or under high CPU load, observed behaviour was:
  - most of the image frames from the cameras appearing on Prime memory PC
  - a small minority of frames appearing on the Redundant Memory PC
- Reason: if the links to the Prime are ever blocked by flow control, the Camera Bricks will send packets to the Redundant router rather than the Prime
- Prevented by setting up both 10X auto-configuration commands to also default both routers to the Prime memory

Space Technology Centre
University of Dundee

Summary of Issues

- ST4 Priority Routing – expected behaviour did not occur
  - Failed to account for header-decode delay
- RT1 Link Redundancy – expected Disable on Silence behaviour did not occur
  - Failed to account for the way in which Disable on Silence functions with Group Adaptive Routing
- RT3 Router Redundancy – after routers have been reset, can not switch to previously used memory, as this is not known
  - solution would require a more sophisticated processor
- Also, when group adaptive routing is used for redundancy, multiple links in a group may be used when available

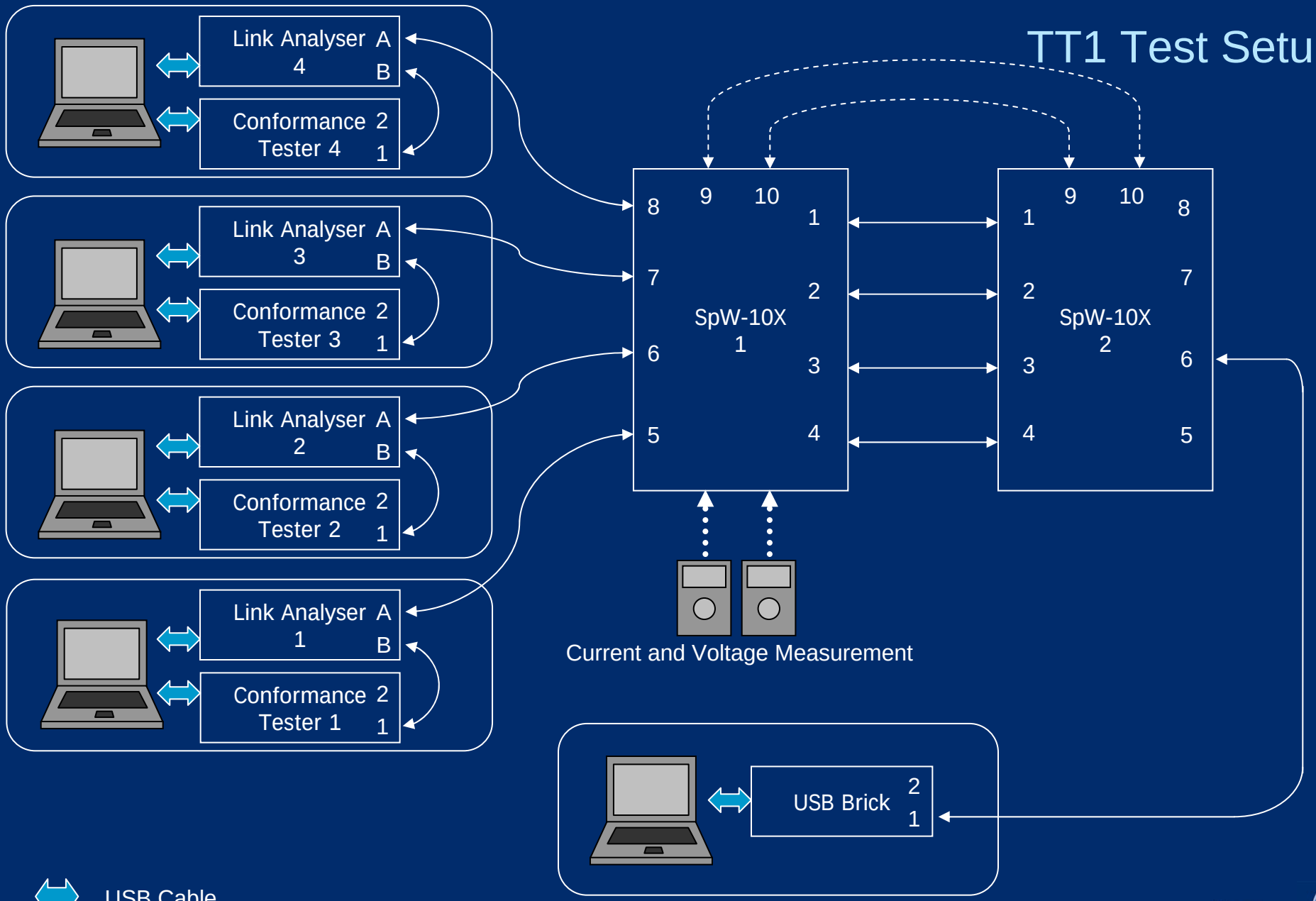
Space Technology Centre
University of Dundee

Additional Observation

Test TT1: Throughput and Power vs. Data Rate

- Objective:
  - This test measures the throughput and power consumption of the SpW-10X device with all links running at various data rates

TT1 Test Setup



Space Technology Centre
University of Dundee

TT1 Power Consumption Results

Space Technology Centre
University of Dundee

Result Set 1	10X number 1 Power Consumption (W)				
	Test 1 (200 Mbits/s)	Test 2 (100 Mbits/s)	Test 3 (50 Mbits/s)	Test 4 (20 Mbits/s)	Test 5 (10 Mbits/s)
Initial	1.54	1.54	1.54	1.54	1.54
After Configuration	1.82	1.57	1.44	1.77	1.54
Start of Test	**2.38**	**1.98**	**1.75**	**2.03**	**1.77**
End of Test	**2.38**	**1.97**	**1.75**	**2.02**	**1.77**
Packet Generators stopped	2.25	1.89	1.71	1.99	1.76

Result Set 2 (Link speeds also set at packet generator)	10X number 1 Power Consumption (W)				
	Test 1 (200 Mbits/s)	Test 2 (100 Mbits/s)	Test 3 (50 Mbits/s)	Test 4 (20 Mbits/s)	Test 5 (10 Mbits/s)
Initial	1.54	1.54	1.54	1.54	1.53
After Configuration	1.82	1.57	1.44	1.76	1.54
Start of Test	**2.38**	**1.88**	**1.60**	**1.84**	**1.59**
End of Test	**2.38**	**1.88**	**1.60**	**1.83**	**1.59**
Packet Generators stopped	2.25	1.80	1.55	1.81	1.57

TT1 Power Consumption Observations

- Power consumption appears to decrease in proportion to decreasing link speed, except in that it increases again at the 20Mbits/s and 10 Mbits/s speeds
  - Reason is due to the way in which each of the signalling rates is achieved within the SpW-10X:

	10X Signalling Rate Settings used to set link speeds				
	Test 1 (200 Mbits/s)	**Test 2 (100 Mbits/s)**	**Test 3 (50 Mbits/s)**	**Test 4 (20 Mbits/s)**	**Test 5 (10 Mbits/s)**
FEEDBDIV	5	5	5	5	5
TXRATE	0	0	0	**9**	**9**
TXDIV	0	1	**2**	0	1
TX10MBITDIV	19	9	4	19	9

Power consumption may be reduced by decreasing FEEDBDIV and increasing TXDIV to achieve the same data rates

Conclusions

Conclusions

- Versatile and flexible hardware created supporting all test scenarios and more
- Extensive testing performed over a period of 4 weeks
- Wide range of test scenarios covered
- Some errors in original test specification
- Router behaves as specified in datasheet
- SpW-10X testing successful